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The Effect of Lateral Deviation on Triple Jump Performance

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THE EFFECT OF LATERAL DEVIATION

ON TRIPLE JUMP PERFORMANCE

by

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ABSTRACT

Field events in track and field consist of throws (e.g., hammer, shot put, discus, javelin), vertical jumps (e.g., pole vault, high jump), and horizontal jumps (e.g., long jump, triple jump). Of the two horizontal jumps, triple jump is the most complex consisting of three phases: hop, step, and jump. Research has been conducted to examine limb motion and phasing distribution during triple jump performance; however, the effect of lateral deviation on triple jump performance in unknown. **Purpose:** The purpose of this study is 1) to determine the effect of lateral deviation on total triple jump performance within high school triple jumpers, and 2) to compare lateral deviation between training ages. **Methods:** High school triple jumpers (training age 2 ± 1.73 yrs, body height 169.33 ± 1.47 cm, body mass 62.75 ± 9.17 kg) performed four jumping trials at maximum effort. Lateral deviation of each step, i.e., hop, step, and jump, and the total jumping distance was measured. **Results:** There was a significant difference in effective and actual distance jumped $p < 0.05$. There was no significant interaction between effective and actual distance, $p > 0.05$. There was no significant difference in distance lost across phases: hop, step, and jump, $p > 0.05$. **Conclusion:** Lateral deviation did cause distance lost during triple jump performance. More investigation is needed to determine underlying causes of lateral deviation.

Keywords: *biomechanics, technique of triple jump, lateral deviation*

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DEDICATION

This thesis is dedicated to all those who motivated and supported me throughout my academic career; also, to the coaches and athletes of Mobile Parks & Recreation Department Track & Field Club and the Ruston High School Track & Field Program for allowing me the opportunity to grow and develop as a track and field coach. Special thanks to Dr. Ben Gleason and Dr. Jean Chen who helped in editing this thesis.

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CHAPTER 1

INTRODUCTION

Track and field is one of the oldest sports dating back to the Olympic Games in Ancient Greece (Newman, 2012). Over the centuries, the sport has adopted new events including long distance running and field events. Among the field events, there are two horizontal jumps: the long jump and the triple jump (Hay, 1993). The triple jump was first introduced during the inaugural 1896 Olympic Games; however, women did not begin to participate in this event until the Atlanta 1996 Summer Olympic Games (Newman, 2012). Within both horizontal jumps, there are four components: running approach, takeoff, flight, and landing (Hay, 1993).

The triple jump consists of three consecutive phases: hop, step, and jump. The phasing consists of an initial takeoff and landing on the same foot, then a step with the opposite foot, and finally a landing in the sandpit (Brimberg, Hurley, & Ladany, 2006). Jumpers typically complete these phases using one of the following two series of foot touchdowns: left-left-right or right-right-left (Newman, 2012). Once the jump is completed, the jump is measured perpendicular to the takeoff board (Hay, 1975; Nelson, 1988). Many variables could affect triple jump performance. The most investigated variables have been phase distribution, limb motion, and approach run (Hay, 1993; Yu & Andrews, 1998; Yu, 1999a). Over the decades, studies have determined the most advantageous arm motion technique (Allen, King, & Yeadon, 2010), trade-offs between horizontal and vertical velocities during triple jump performance (Allen et al., 2013), and optimization of phase ratio in triple jump performance Allen et al. 2016). One area of triple jump performance that has not been investigated thoroughly is the effect of lateral deviation. It has been suggested that due to jump measurement being measured perpendicular to the takeoff board, jumpers should jump at right angles to the board to gain the most effective jump distance (Hay, 1975). Hay and Miller (1986) claimed that lateral deviation from a straight line path – from the initial takeoff – have little to no effect on measured distance of each triple jump phase. This is an important research topic because minimal research has been conducted. If lateral deviation does affect triple jump performance, jumpers could be losing distance from their effective jump. Hay (1975) found that lateral deviation of at least 18 inches (i.e., 0.457 m) costs the jumper less than 1 inch in effective jumping distance across any given phase; however, when deviation was at least 9 inches (i.e., 0.229 m), it costs the jumper ¼ of an inch in effective jumping distance .

When analyzing recent High School Boy's triple jump results, it is evident the significance of losing ¼ an in effective jumping distance. For example, a quarter of an inch separated 4^{th} and 5^{th} place and 5^{th} and 6^{th} place. In a scoring meet, there is a two point difference in 4^{th} and 5^{th} place and a one point difference in 5^{th} and 6^{th} place. These point differences could be the difference between a team ranking first place or another placement (Figure 1-1).

Seed	Finals	Wind		Points
44-05.00	44-11.50	NWI	13.70m	10
43-10.00	44-03.00	NWI	13.48m	8
42-02.00	42-10.25	NWI	13.06m	6
39-00.50	42-07.00	NWI	12.97m	4
43-11.00	42-06.75	NWI	12.97m	2
43-09.50	42-06.50	NWI	12.96m	1
41-11.50	42-05.50	NWI	12.94m	
40-09.00	42-05.25	NWI	12.93m	
43-03.00	41-10.50	NWI	12.76m	
41-02.00	41-08.75	NWI	12.71m	
40-00.50	41-07.75	NWI	12.69m	
40-03.00	40-07.00	NWI	12.36m	

Figure 1-1: Example case jumps being separated by a quarter of an inch

The purpose of this study is to 1) determine the effect of lateral deviation on total triple jump performance within high school triple jumpers and 2) compare lateral deviation between training ages. In general, jumpers may be expected to lose jump distance due to lateral deviation. Based on previous literature, it is hypothesized that 1) lateral deviation will have no effect on triple jump performance; and 2) high school triple jumpers of younger training age will have a greater deviation than jumpers of an older training age~~.~~. Results of this study will contribute to determining key variables that optimize triple jump performance.

CHAPTER 2

LITERATURE REVIEW

Most of the literature evaluating triple jump performances are reviews summarizing or identifying researchers' limitations and theoretical and practical findings from coaches' or researchers' opinions (Hay, 1992; Yu, 1999a). Many of these reviews provided rationales evaluating the effects of specific techniques on triple jump performance. Specific techniques that have been investigated the most are phase distribution (Hay, 1993), arm swing motion (Yu & Andrews, 1998), and approach run (Yu, 1999a). Other investigated variables include biomechanical loading such as ground reaction force and plantar pressure (Ramey & Williams, 1985; Perttunen, Kyrolainen, Komi, & Heinonen, 2000), horizontal to vertical velocity conversion (Fukashiro, Iimoto, Kobayashi, & Miyashita, 1981), and runway run approach (Yu, 1999a). Over the decades, the available literature has grown and more studies need to be conducted to include and confirm findings.

2.1 Optimal Phase Distribution Techniques

According to Yu (1999a), optimum phase-ratio is the most important consideration in the triple jump and should be the main focus before other technique variables. Phase-ratio is the indirect measure of effort distribution and has three components: the takeoff, flight, and landing (Yu, 1999a). It has been observed that the flight portion of each phase has the greatest effect on the total jumping distance (Yu, 1999a). This component of the phase has a common coaching cue, referred to as "riding the phase." The longer the "ride" the greater the distance achieved in each phase of the jump. Generally, the first two phases – the hop and step – are performed at sub-maximal effort while the last phase – the jump – is performed with maximal effort (Hay 1993). This is a requirement to be successful in the triple jump (Hay, 1992).

Three techniques of phase distribution have been identified to optimize total jumping distance: hop-dominant, jump-dominant, and balanced (Hay, 1992). In hop-dominant technique the hop phase is the longest of all preceding phases. In contrast, in jump-dominant technique, the jump phase is the longest of all previous phases. Lastly, in the balanced technique, the distance gained is similar across each phase.

Past studies have encountered challenges in determining effort distribution and quantifying trial-to-trial variability in the triple jump (Hay, 1992). Recent studies have tried to account for these limitations through the use of multiple jumping trials to record multiple data points and video recording of jumps to review phase distribution. When investigations of phase distribution began, hop-dominant and balanced techniques were considered to be optimal (Hay, 1992).

Simpson, Wilson, & Kerwin (2007) compared effort distribution between eight novice and five experienced triple jumpers. They found that novice jumpers employed jump-dominant techniques, while experienced jumpers employed hop-dominant techniques. Novice jumpers tended to shorten their step phase, using it as a transitional step between the hop and jump phases. The experienced jumpers elongated their step phase, thus producing greater total jumping distance. Allen and colleagues (2016) studied the effect of employing balanced, hop-, or jump-dominant phasing technique during the triple jump and found similar results using computer simulation. For this specific athlete, the hop-dominant technique was found to be the most optimal. Trial-to-trial, total jump distance increased and then plateaued for both balanced and hop-dominant techniques; however, total jump distance decreased trial-to-trial for the jump-dominant technique. However, new record holders and winners of the 1990s preferred the jump-dominant technique (Brimberg, Hurley, & Ladany, 2006; Hay, 1993; Miller & Hay, 1986).

2.2 Optimal Arm Swing Technique

Over the years, three common arm actions have been identified: single arm swing, double arm swing, and arm-and-half swing (Hay, 1992; Yu, 1999a). Single or alternate arm swing is defined as a forward and backward motion opposite of the stance and free leg motions, mimicking sprint mechanics. In contrast, the double arm swing is defined as both arms simultaneously starting behind the jumper, driving through in a downward then upward-forward motion. The arm-and-a-half swing technique is a mix of the two previous techniques, where the ipsilateral arm, to the takeoff leg, mimics sprinting mechanics while the contralateral arm is carried overhead in front of the jumper before taking off; both arms are then driven to shoulder level during the takeoff phase (Hay, 1992; Yu, 199a).

Investigations on limb motion have determined that during each stance phase, limbs act independently during each phase (Yu, 1999a). Yu and Andrews (1998) studied 13 elite triple jumpers' performances during the 1992 US Olympic Trials and found that free limb motion contributed to a decrease in forward horizontal velocities during both the stance and jump phase. However, there was a gain in vertical velocity across all phases with the use of free limb motion. There have been mixed findings in arm swing actions during the triple jump (Hay, 1992).

Past studies have found that jumpers might employ multiple arm action techniques within one jump and may vary between jumping trials (Hay, 1992). Twenty-seven different possible combinations have been identified. Yu (1999a) found that the ratio of loss in horizontal velocity to gains in vertical velocity was greatest in double arm swing and lowest in single or alternate arm swing. It has been suggested that jumpers should perform a single arm technique during the hop and step phase and double arm swing during the jump phase (Hay, 1992; Yu, 1999a). Recently, Allen and colleagues (2010) used a computer simulation to determine an optimal arm swing technique for the triple jump. Using a single-subject, double arm swing technique was found to be more advantageous than the single arm swing technique. This was due to possible optimization of both ground contact time and vertical reaction impulses across all phases.

2.3 Approach Run Velocity and Other Velocities

Other factors that contribute to triple jump performance are approach run, conversion of horizontal-to-vertical velocity, and horizontal velocity of the body's center of mass (Allen et al., 2013; Hay, 1992; Nelson, 1988; Panoutsakopoulos et al., 2016; Yu, 1999a; 1999b). The approach run is a purposeful preliminary requirement to the angular projection of the body for horizontal distance. The approach run has two phases: the acceleration phase – which includes the first 8-16 steps, and the preparation phase – which includes the final 4-6 steps before takeoff (Panoutsakopoulos et al., 2016). A difference between approach velocities has been found between long jumpers and triple jumpers, with the latter tending to approach the board at lower velocity (Hay, 1993). Hay (1995) suggested that if triple jumpers do not limit their approach velocity, they may not be able to handle initial takeoff of the hop and maintain balance. Liu, Mao, & Yu (2015) studied 13 elite triple jumpers' performance during the 1992 US Olympic Trials and found that the greater the horizontal velocity of the run approach, the greater the optimal phase percentages for both the hop and jump phases.

In more recent years, researchers have investigated horizontal-to-vertical tradeoffs in relations to the velocity conversion coefficient (Allen et al., 2013; Lui et al., 2015; Yu, 1999b). The velocity conversion coefficient ($\mathbf{A_1}$) is the theory that losses in horizontal velocity can be expressed as a linear function of gains in vertical velocity (Yu, 1999a). Many studies have found that the magnitude of $\mathbf{A_1}$ has an effect on horizontal-to-vertical velocity tradeoffs and in turn affects total jump distance (Allen et al., 2013; Lui et al., 2015; Yu, 1999b). When 10 elite triple jumpers' performances were studied, it was found that with small gains in vertical velocity there was a greater magnitude of $\mathbf{A_1}$. However, with large gains in vertical velocity, the $\mathbf{A_1}$ was lower in magnitude (Yu, 1999b). In both instances, the losses of horizontal velocity were smaller the losses of vertical velocity.

Other factors can such as active, and block landing can also affect approach run velocity and other velocities. Active landing is defined as the backward sweep of the stance leg in which the center of mass is directly over the stance leg (Koh & Hay, 1990a, 1990b). Block landing is when the center of mass is behind the stance leg before takeoff (Koh & Hay, 1990a, 1990b). When comparing the data of the top four finishers of the 1985 TAC Championships to other elite triple jumpers, it was found that more advanced jumpers use an active landing leg motion prior to takeoff of the step phase and then employ the blocking technique prior to takeoff into the jump phase (Miller & Hay, 1986).

2.4 Conclusion

Specific techniques could be advantageous to triple jump performance, however some debate exists. Major techniques to consider are optimal phase distribution, arm swing motions, and approach runs velocities. Many studies have identified hop-dominant technique as superior; however, over the past decades, there has been a shift in what is considered optimal phase distribution (Brimberg et al., 2006; Hay, 1995). It has been suggested that jump-dominant technique allows for greater initial velocities for the hop phase, and thus, it improves overall jump performance (Brimberg et al., 2006). At this point, phasing has not been studied in combination with other variables such as lateral deviation or arm swing. Hay (1975) suggested that deviation up to 18 inches could cost a jumper 1 inch in the distance in a given phase, and deviation up to 9 inches could cost ¼ inch. Therefore, it is of value to investigate phasing distribution in the context of lateral deviation and arm swing motions.

Although some progress has been made in recent years, further investigation is needed to compare the effectiveness of each arm action technique. It has been suggested that the most optimal arm swing technique is a combination of single- and double-arm swings: single-arm swing during the hop and step phase and double-arm swing during the jump phase (Yu, 1999a). However, Allen and colleagues (2010) identified a double-arm swing technique to be most optimal in jump performance. Further investigations are needed in this area in combination with other variables such as phase distribution and lateral deviation.

Approach run velocity is an influencing factor in triple jump performance. Many studies have evaluated the final steps of the run approach, but very few have observed full approach run. Maraj, Allard, and Elliott (1998) observed the final 11 approach run steps in non-elite jumpers while investigating competition constraints such as control, distance, and accuracy. When performing the distance condition, jumpers were significantly faster than both the control and accuracy conditions. In a similar study, youth triple jumpers' full approach runs were analyzed with varied environmental and task factors (Panteli, Simrniotou, & Theodoroi, 2016). Similar results were found. It is suggested that the optimal technique may not just depend on the above variables but also on individual differences (Hay, 1992; Yu, 1999a).

CHAPTER 3

METHODS

3.1 Participants

Participants were three (2, females; 1 male) high school jumpers (training age 2 ± 1.73 yrs, body height 169.33 ± 1.47 cm, body mass 62.75 ± 9.17 kg) from the southeastern region of the United States. To be eligible for this study, participants had to have at least one season of training experience with no injuries of the lower extremities in the past three months.

Participant	**Training Age (yr)**	**Body Height (cm)**	**Body Mass(kg)**
1	1	167.64	54.43
2	4	170.18	61.24
3	1	170.18	72.57

Table 3-1:Description of participants.

3.2 Procedures

3.2.1 Screening.

During screening, participants were encouraged to discuss the contents of the informed consent form, and ask questions to the researchers. Required study tasks and potential risks were carefully explained to all participants and legal guardian(s). After this process, participants signed an informed consent form (Appendix B.1). Participants under the age of 18 were required to have the parental consent form (Appendix B.2) signed by a legal guardian. Also, the participant under the age of 18 was required to sign an assent form (Appendix B.3). Once the forms were signed, participants were asked about their health (e.g., past injuries) and training history to determine if they were eligible for this study. Height and body mass were measured during this time.

3.2.2 Warm-up.

Participants completed a 30-45 minute warm-up, including one-lap jog around the location's outdoor track at no slower than an 8-minute mile pace (2-minute lap). This was followed by active dynamic stretching. A specific warm-up included eight drills, four 50-meter accelerations, and pit drills guided by the investigator. All participants performed the same standardized warm-up. All warm-ups and drills were done in training shoes, but changed into jumping spikes before jumping

3.2.3 Tasks.

Participants were randomly ordered for trials and jump in the same order throughout data collection. Each participant was allowed four jumps from full approach at maximum effort. If participant stepped over the takeoff board, the jump still counted towards their attempt. Between each jump, the runway was swept, using a broom, to remove footprints of the previous jumper. The sandpit was also raked to provide a consistent landing surface for the next jumper (Figure 3-1).

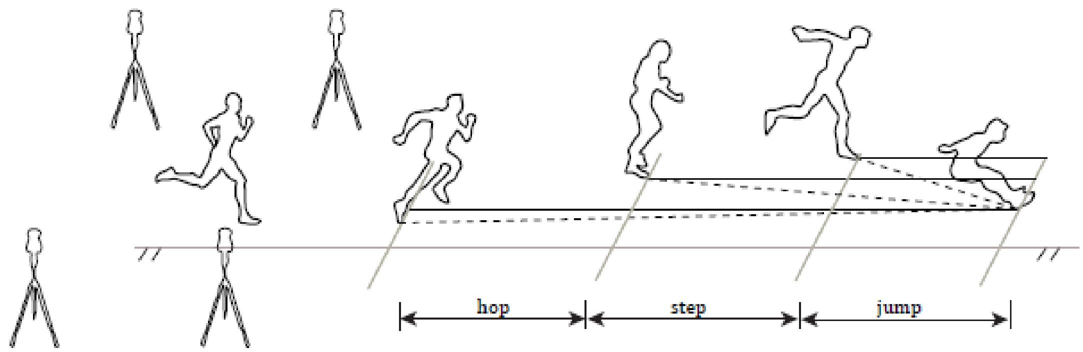

Figure 3-1: Triple jump performance and study set-up.

3.2.4 Cool-down.

Participants completed a 15-minute cool-down after the study, after changing back into training shoes. The cool-down included a one-lap jog around the track at a slower pace(3-minute lap) compared to the warm-up lap. This was followed by static stretching guided by the investigator. All participants performed the same standardized cool-down. Cool-down was done in training shoes.

3.3 Measurements

3.3.1 Effective Jump.

Eight measurements were taking for each jumping trial using a standardized tape measure. Total effective jump (TJED) measurements were taken by placing the tape measure perpendicular to the takeoff board (midline) and measure the jump as it lines with this midline. In addition, effective measurements were taken between the takeoff board and hop phase landing (HED), hop phase landing and step phase landing (SED), and step phase landing and jump phase landing (JED). If the participant fouled, the tape was placed at the point of takeoff in front of the toe. For all other foot placements, measurement started at the toe and ended at the heel. This was also performed for actual jump distance.

3.3.2 Actual Jump. Total actual jump (TJAD) measurements were taken by placing the tape measure perpendicular to the takeoff board (midline) and pulling the tape in the pathway of the landing position of the jump. In addition, actual measurements were taken between the takeoff boards and hop phase landing (HAD), hop phase landing and step phase landing (SAD), and step phase landing and jump phase landing (JAD) (Figure 3-2).

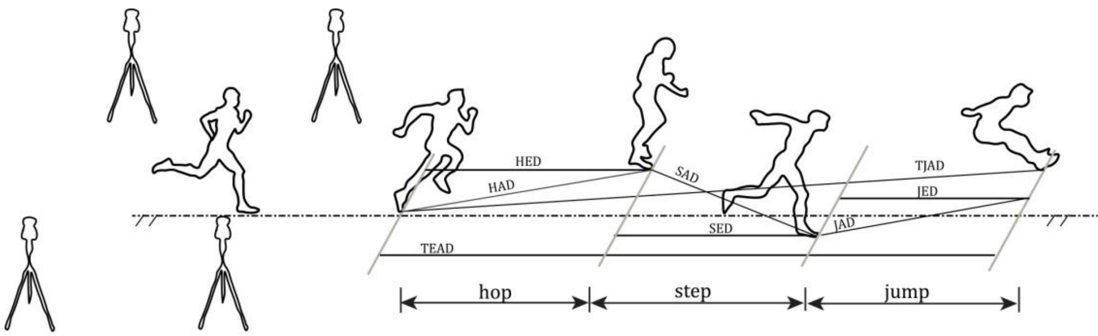

Figure 3-2: Effective and actual distance measurements.HED = hop effective distance, SED = step effective distance, JED = jump effective distance, TJED = total jump effective distance, HAD = hop actual distance, SAD = step actual distance, JAD = jump actual distance, TJAD = total jump actual distance.

3.3.3. Distance Lost.

Distance lost (DL) was calculated using the equation from Hay (1975) with modifications. The original equation was said to be derived from Pythagorean Theorem in which a2 + b2 = c2. In his equation, the correct mathematical steps were not taken. For this study, correct mathematical procedures were taken to calculate DL. Variables equivalent to Pythagorean Theorem are as followed: DL = a, ED = b, and AD = c. The equation used for this study is as follows:

Eq 1:. DL = $\sqrt{AD^2 - ED^2}$

3.3.4. Time.

Four timing gates (Brower Timing System, Draper, UT) were used to measure the intervals of each phase within the participants' jumping trials. Two gates were placed 0.61m after initial runway approach and 0.61m before the takeoff board. Gates placed at these distances to capture the in-flight phase of the participants' runs. This helped control for the possibility of the arm breaking the beam before the body and also, possible deceleration right before takeoff.

3.4 Statistical Analysis

Descriptive statistics was run on all data. Percent differences were determined for total jump performance groups. Other statistical analyses ran included correlations, one repeated measure ANOVE, and ond2 × 4 repeated measures factorial ANOVA (Keppel and Wickens, 2004). The factors of the ANOVA were distance and phase. There were two levels within distance: effective and actual. There were four levels within each phase: hop, step, jump and total jump. All calculations including statistics were performed using MATLAB (R2013b, MathWorks, Inc., Natick, MA, USA). All values are mean ± standard deviation, except where indicated.

CHAPTER 4

RESULTS

4.1 Triple Jump Performance

A 2 × 4 Factorial ANOVA showed that there was a significant difference in TJED (p = 0.04) and TJAD (p = 0.00). However, the interaction between the two jump performances was not significant (p = 0.33) (Figure 4-1).

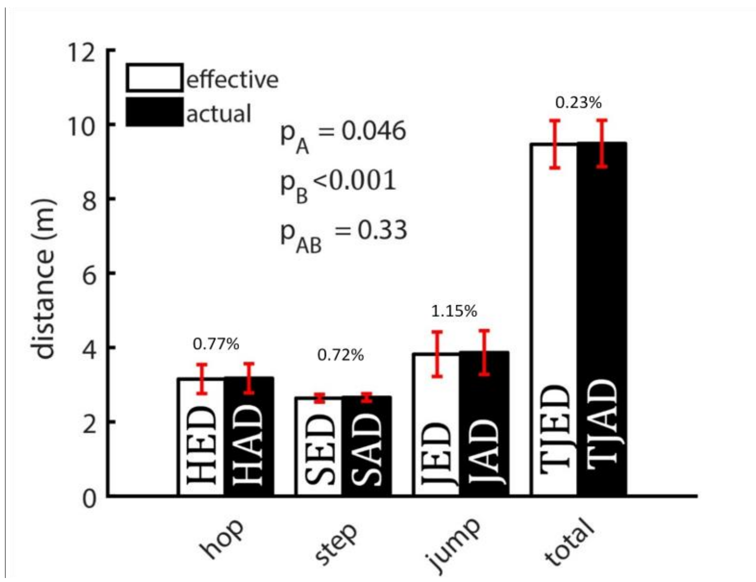

Figure 4-1: Effective and actual jumping distance across each phase. PA = effective, PB = actual, and PAB = interaction between effective and actual distance.

This indicates that the difference between total jump effective and actual distance are independent of each other.

4.1.1 Effective Jump Performance.

Effective measures for each phase were as follows: HED was 3.15 ± 0.46m, SED was 2.64 ± 0.31m, and JED was 3.82 ± 0.54m (Figure 4-2). Total effective jump performance was 9.47 ± 0.64m (Figure 4-1).

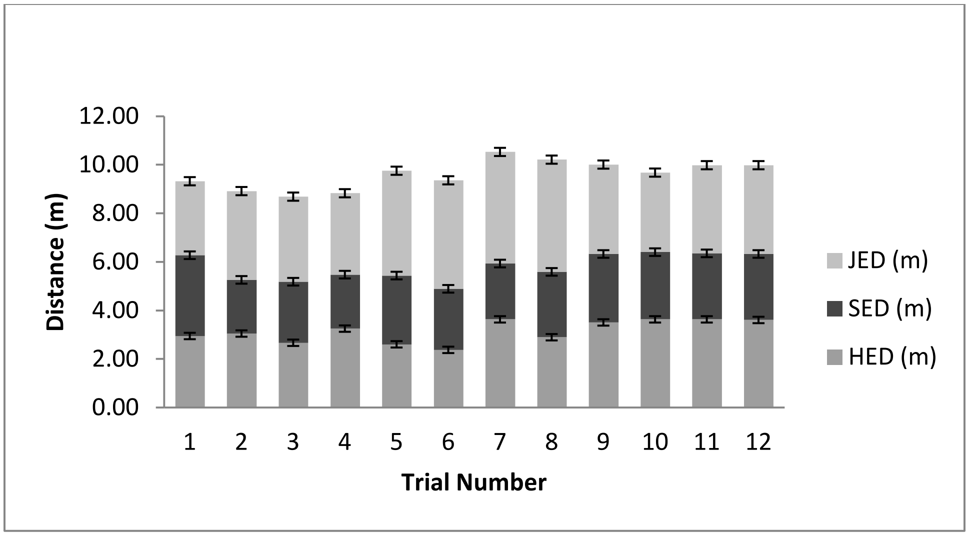

Figure 4-2: Effective phasing distance across all trials.JED = jump effective distance, SED = step effective distance, and HED = hop effective distance.

4.1.2 Actual Jump Performance.

Actual measures for each phase were as follows: HAD was 3.14 ± 0.46m, SAD was 2.66 ± 0.32m, and JAD was 3.86 ± 0.54m (Figure 4-3). Total actual jump performance was 9.49 ± 0.63m (Figure 4-2).

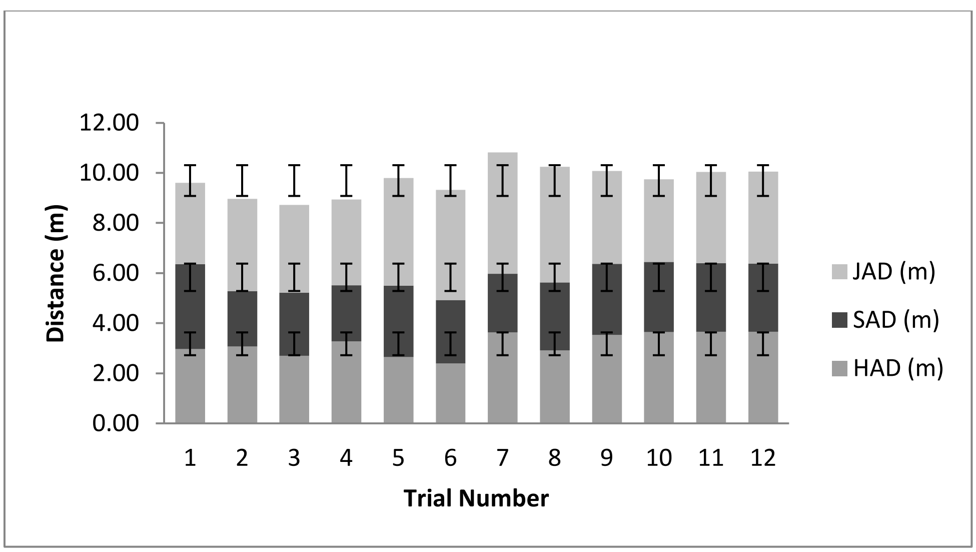

Figure 4-3: Actual phasing distance across all trials. JAD = jump actual distance, SED = step actual distance, and HAD = hop actual distance.

4.1.3 Gender Difference in Jump Performance.

(Male) Phase	M ± SD
HED	2.88 ± 0.55
SED	2.58 ± 0.23
JED	4.50 ± 0.14
TJED	9.87 ± 0.52

Table 4-1:Effective measures for each phase for male participant.

(Females) Phase	M ± SD
HED	3.29 ± 0.37
SED	2.66 ± 0.36
JED	3.48 ± 0.23
TJED	9.27 ± 0.62

Table 4-2: Effective measures for each phase for female participants.

4.2 Distance Lost due to Lateral Deviation

A repeated measures ANOVA showed that there was no significant difference in distance lost between each phase, $p = 0.26$ (Figure 4-4).

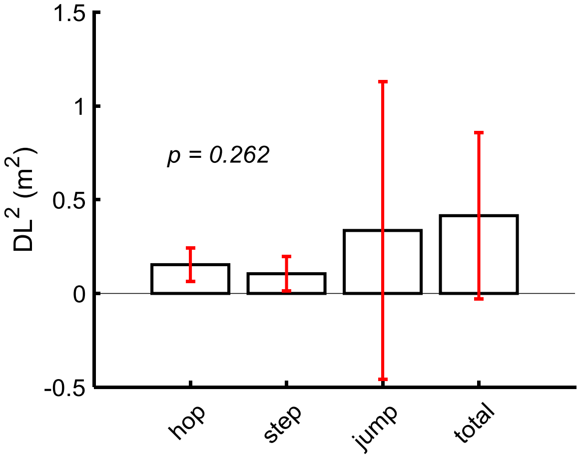

Figure 4-4: Distance lost across triple jump performance. DL = distance lost.

Distance lost due to lateral deviation for each phase was 0.37 ± 0.14m for hop, 0.28 ± 0.16m for step, 0.33 ± 0.64m for jump, and 0.58 ± 0.48m for total jump performance (Figure 4-5).

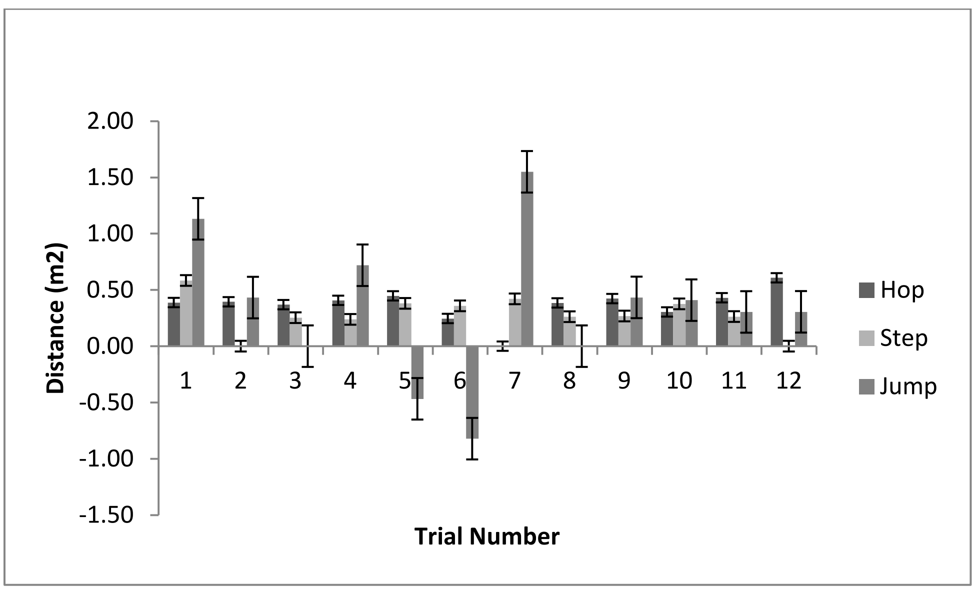

Figure 4-5: Comparison of distance lost between each trial across each phase within the triple jump.

CHAPTER 5

DISCUSSION AND CONCLUSION

5.1 Discussion

The purpose of this study was to determine the effects of lateral deviation on triple jump performance. It was expected that lateral deviation would cause distance lost across each triple jump phase, resulting in a decrease in total jump performance. Significant differences in effective distance (i.e., TJED) and actual distance (i.e., TJAD) were observed ($p < 0.05$). This indicates that lateral deviation did have an effect on triple jump performance, which differs from the findings of Hay (1975). Differences in findings may be due to that this study evaluated the effect across the full jump performance, where Hay (1975) only looked at the effect within a given phase. On average, most distance lost was during the hop and the least distance lost was during the step (Figure A-1-3). With the experience level of the participants, this observation seems to be reasonable. It would be logical to assume that less experience jumpers would have more technical flaws than more advanced triple jumpers.

Factors that may have contributed to greater distance lost in the hop could be: inability to convert approach velocity into takeoff velocity, keep the body aligned in the path of the jump, or lack of control of the jump (Hay, 1975; 1995). Simpson and colleagues (2007) found that novice jumpers tended to shorten their step phase, as the step acted as a transitional step between the hop and jump.

No significant differences were found between distance lost across each phase and lateral deviation, $p = 0.26$. Interestingly, jumpers with a greater training age tended to have a greater distance lost. However, jumpers with greater training age also tended to be faster on their run approach. However, these differences were not significant (p =0.26).

5.2 Conclusion

In general, distance was lost during the triple jump performance due to lateral deviation. Based on results, jumpers with a greater training age had greater distance lost across the hop, jump, and total jump distance. Greater variability of training ages is need before generalizing this to all triple jumpers. There was no significant difference in distance lost across phases.

5.2.1 Limitations. There were three participants for this study; causing a lack of variability in gender and training age. Lack of participants may be due to the time of year (post-season championships) and strict criteria on injuries. With this being an acute study, long term effects of deviation is not well known.

5.2.2. Delimitations. Jumpers could not have had an injury of the lower extremities in the past three months. This criterion was set to help lower risk of injury. Future studies may not have to be as restrictive. Also, jumpers had to have a minimum of one season of training experience to reduce the possibility of learning effect on total jump performance.

5.3 Future Research

The current study focuses solely on the acute effects of lateral deviation on triple jump performance. The results have show that lateral deviation leads to distance lost, which affects total jump performance. However, the current study does not identify the underlying causes of lateral deviation. One variable worth investigating is the effect of approach velocity on lateral deviation. A correlation was found between approach velocity and distance lost across hop, step, and jump; $R^2 = 0.14$, $R^2 = 0.08$, $R^2 = 0.04$, respectively. In general, those with greater approach velocity tended to have greater distance lost during the hop phase (Figure A-4). This may be due to the individual jumper's inability to convert their approach velocity into takeoff velocity; leading to the jumper's inability to control the actual triple jump. It has been suggested that if a jumper does not limit their approach velocity they may not be able to handle the initial takeoff of the hop and maintain balance (Hay, 1995).

Another variable worth investigating is the effect of arm swing motion on lateral deviation. In the current study, the individual who employed single arm swing (1) had greater distance lost across each phase compared to individuals who employed a double arm swing motion (2). The use of the single arm swing may have caused a greater trunk rotation leading to the jumper's inability to control their balance. Therefore, the use of double arm swing may have enhanced other jumpers' ability to maintain balance and control throughout the jump. Recently double arm swing technique was found to be more advantageous than single arm swing technique (Allen et al., 2010). With further investigation of the above variables, researchers can become closer to identifying underlying causes of lateral deviation during triple jump performance.

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APPENDIX A

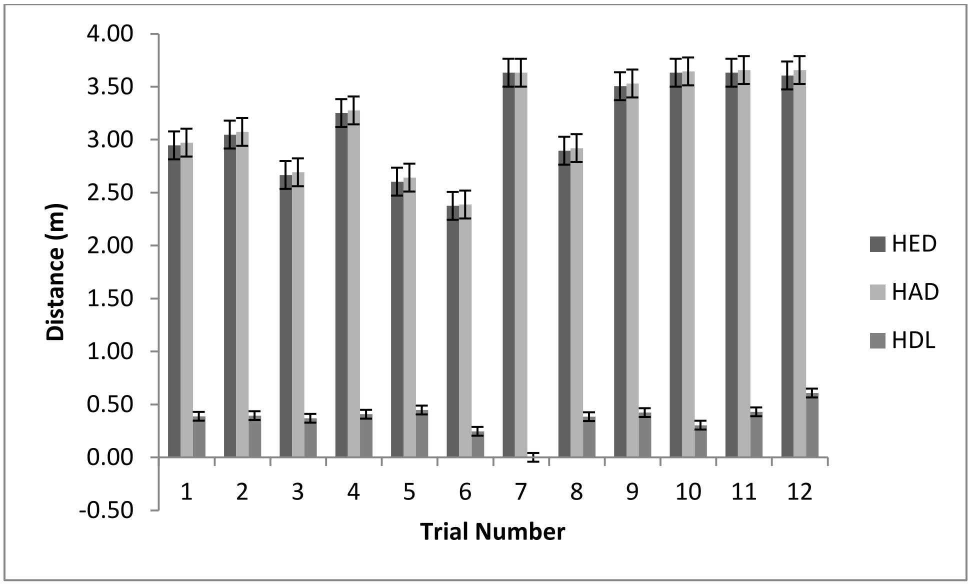

Figure A-1: Comparison of effective, actual, and distance lost across all trails in the hop phase. HED = hop effective distance, HAD = hop actual distance, HDL = hop distance lost.

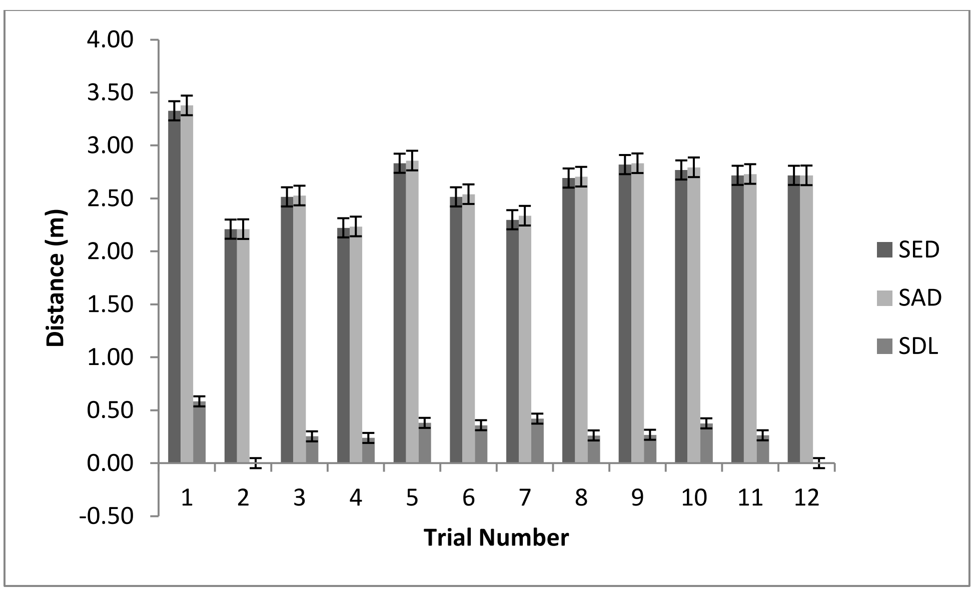

Figure A-2: Comparison of effective, actual, and distance lost across all trails in the step phase. SED = step effective distance, SAD = step actual distance, SDL = step distance lost.

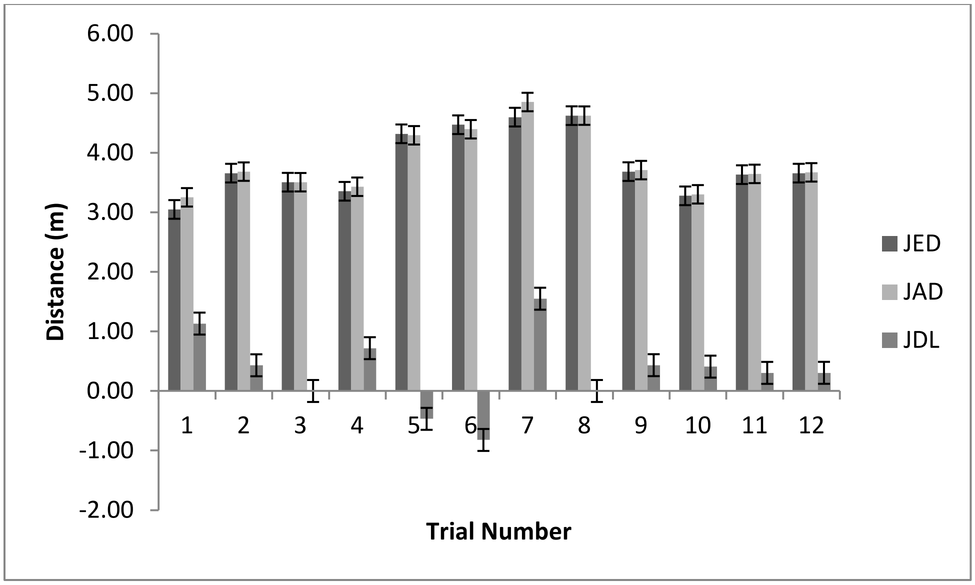

Figure A-3: Comparison of effective, actual, and distance lost across all trails in the jump phase. JED = jump effective distance, JAD = jump actual distance, JDL = jump distance lost.

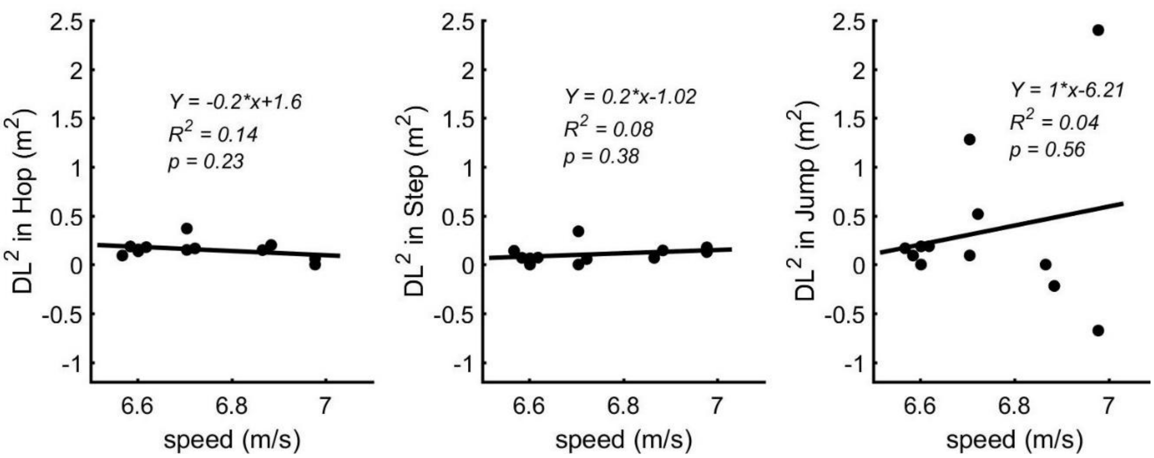

Figure A-4: Correlation between speed and DL across each phase. DL = distance lost.

APPENDIX B

B.1 Informed Consent Form

HUMAN SUBJECTS CONSENT FORM

The following is a summary of the project in which you are asked to participate. Please read this information before signing the statement below. You must be of legal age (18yrs) or must be co-signed by a parent or guardian to participate in this study.

TITLE OF PROJECT: THE EFFECT OF LATERAL DEVIATION ON TRIPLE JUMP PERFORMANCE

PURPOSE OF STUDY/PROJECT:
The purpose of this study is to investigate the effect of lateral deviation on triple jump performance within high school and collegiate triple jumpers.

SUBJECTS:
High school and collegiate triple jumpers between ages 16-24, with least one season training experience with no injuries of the lower extremities in the past 3 months.

PROCEDURE:
Interview and Screening: During the interview and screening, you will have the opportunity to discuss the contents of the informed consent form, as well as ask questions. If you agree to participate in the study, you will be asked a question about your health and training history to determine you are eligible for this study.

1) **Warm up**: You will be allowed a 30-45 minutes warm-up to lower the potential risk of injury. A general warm-up will include jogging 1-lap around the local outdoor track followed by active dynamic stretching (15 minutes). A specific warm-up will include drills, buildups/accelerations, and pit drills guided by the lead investigator (15-30 minutes).

2) **Tasks:** you will be randomly ordered for trials and jump in the same order throughout data collection. You will be allowed four jumps at maximum effort. After the trials, you will complete a cool down. The cool down will include jogging 1-lap around the local outdoor track followed by static stretching. Static stretching will be guided by the lead investigator (10-15 minutes).

3) **Data Collection:** Three measurements will be taken: 1) Jumping distance as it aligns with the midline of the runway area. 2) Jumping distance where the tape is placed at the midline of the take-off board and pulled in the pathway of the landing position of the jump phase. 3) The distance between the midline and the landing position for each phase.

BENEFITS/COMPENSATION:
By participating in this study, it will be a better understanding of the effects of lateral deviation on triple jump performance. Also, at the conclusion of data collection, you will be given constructive criticism to help improve your future triple jump performances.

RISKS, DISCOMFORTS, ALTERNATIVE TREATMENTS:
The following are potential physical risks that may occur during data collection for this study:

- The task may have the risk of a knee injury or spraining the ankle. These risks are minimized because running approach speeds will be self-selected by each participant. Also, you are recommended to wear appropriate knee/ankle brace(s) and required to wear appropriate shoes. Furthermore, the warm-up prepares the lower extremities for activity and decreases the risk or injury. Finally, the risk of injury is minimized because you are required to have at least one season of triple jump training with no history of injury in the past three months.

All of the above risks are well-known and documented. Procedures are in place to minimize potential risk; however, there is a possibility that you may be subject to risks that have not been mention*. If at any point, you feel the need to withdraw from the study, you will be allowed to stop immediately.*

The participant understands that Louisiana Tech is NOT able to offer financial compensation nor to absorb the costs of medical treatment should you be injured as a result of participating in this research.

The following disclosure applies to all participants using online survey tools: This server may collect information and your IP address indirectly and automatically via "cookies."

I, ___________________, attest with my signature that I have read and understood the following description of the study, "(THE EFFECT OF LATERAL DEVIATION ON TRIPLE JUMP PERFORMANCE)," and its purposes and methods. I understand that my participation in this research is strictly voluntary and my participation or refusal to participate in this study will not affect my relationship with Louisiana Tech University or my grades in any way. Further, I understand that I may withdraw at any time or refuse to answer any questions without penalty. Upon completion of the study, I understand that the results will be freely available to me upon request. I understand that the results of my survey will be confidential, accessible only to the principal investigators, myself, or a legally appointed representative. I have not been requested to waive nor do I waive any of my rights related to participating in this study.

Subject's Signature	Printed Name	Date
Investigator's Signature	Printed Name	Date

CONTACT INFORMATION: The principal experimenters listed below may be reached to answer questions about the research, subjects' rights, or related matters.

Principal Investigator:

Kourtney S. Jones, M.S.
Graduate Teaching Assistant
Department of Kinesiology
Louisiana Tech University
Phone: (251) 654-2356
Email: kjo016@latech.edu

Co-Investigator:

Mu Qiao, Ph.D.
Assistant Professor
Department of Kinesiology
Louisiana Tech University
P.O. Box 3176
236 Memorial Gym
Ruston, LA 71272
Office: (318)257-5467
Email: mqiao@latech.edu

Members of the Human Use Committee of Louisiana Tech University may also be contacted if a problem cannot be discussed with the experimenters:

Dr. Richard Kordal,
Director, Office of Intellectual Property & Commercialization
Ph: (318) 257-2484,
Email: rkordal@latech.edu

B.2 Parental Consent Form

HUMAN SUBJECTS PARENTAL CONSENT FORM

The following is a summary of the project in which your child is asked to participate. Please read this information before signing the statement below.

TITLE OF PROJECT: THE EFFECT OF LATERAL DEVIATION ON TRIPLE JUMP PERFORMANCE

PURPOSE OF STUDY/PROJECT:
The purpose of this study is to investigate the effect of lateral deviation on triple jump performance within high school and collegiate triple jumpers.

SUBJECTS:
High school and collegiate triple jumpers between ages 16-24, with least one season training experience with no injuries of the lower extremities in the past 3 months.

PROCEDURE:
If you allow your child to participate in this research study, they will participate in the task outlined below:

Interview and Screening: During the interview and screening, you and your child will have the opportunity to discuss the contents of the informed consent form, as well as ask questions. If you agree, your child will be asked question about their health and training history to determine if he/she is eligible for this study.

4) **Warm up**: Your child will be allowed a 30-45 minutes warm-up to lower potential risk of injury. A general warm-up will include jogging 1-lap around the local outdoor track followed by active dynamic stretching (15 minutes). A specific warm-up will include drills, buildups/accelerations, and pit drills guided by the lead investigator (15-30 minutes).

5) **Tasks:** Your child will be randomly ordered for trials and jump in the same order throughout data collection. Your child will be allowed four jumps at maximum effort. After the trials, you will complete a cool down. The cool down will include jogging 1-lap around the local outdoor track followed by static stretching. Static stretching will be guided by the lead investigator (10-15 minutes).

6) **Data Collection:** Three measurements will be taken: 1) Jumping distance as it aligns with the midline of the runway area. 2) Jumping distance where the tape is placed at the midline of the take-off board and pulled in the pathway of

the landing position of the jump phase. 3) The distance between the midline and landing position for each phase.

BENEFITS/COMPENSATION:
By participating in this study, the will be a better understanding of the effects of lateral deviation on triple jump performance. Also, at the conclusion of data collection your child will be given constructive criticism to help improve their future triple jump performances.

RISKS, DISCOMFORTS, ALTERNATIVE TREATMENTS:
The following are potential physical risks that may occur during data collection for this study:

- The task may have the risk of a knee injury or spraining the ankle. These risks are minimized because running approach speeds will be self-selected by each participant. Also, your child is recommended to wear appropriate knee/ankle brace(s) and required to wear appropriate shoes. Furthermore, the warm-up prepares the lower extremities for activity and decreases the risk or injury. Finally, the risk of injury is minimized because you are required to have at least one season of triple jump training with no history of injury in the past three months.

All above risks are well-known and documented. Procedures are in place to minimize potential risk; however, there is a possibility that you may be subject to risks that have not been mention*. If at any point, you or your child feels the need to withdraw from the study, they will be allowed to stop immediately.*

The parent/legal guardian understands that Louisiana Tech is NOT able to offer financial compensation nor to absorb the costs of medical treatment should your child become injured as a result of participating in this research.

The following disclosure applies to all participants using online survey tools: This server may collect information and your IP address indirectly and automatically via "cookies."

I, ___________________, attest with my signature that I have read and understood the following description of the study, "(THE EFFECT OF LATERAL DEVIATION ON TRIPLE JUMP PERFORMANCE)," and its purposes and methods. I understand that my child's participation in this research is strictly voluntary and my child's participation or refusal to participate in this study will not affect their relationship with Louisiana Tech University or their grades in any way. Further, I understand that my child may withdraw at any time or refuse to answer any questions without penalty. Upon completion of the study, I understand that the results will be freely available to me upon request. I understand that the results of my

survey will be confidential, accessible only to the principal investigators, myself, or a legally appointed representative. I or my child have not been requested to waive nor do I or my child waive any of my rights related to participating in this study.

Signature of Parent/Guardian________________________________ Date ____________

Name of child
____

CONTACT INFORMATION: The principal experimenters listed below may be reached to answer questions about the research, subjects' rights, or related matters.

Principal Investigator:

Kourtney S. Jones, M.S.
Graduate Teaching Assistant
Department of Kinesiology
Louisiana Tech University
Phone: (251) 654-2356
Email: kjo016@latech.edu

Co-Investigator:

Mu Qiao, Ph.D.
Assistant Professor
Department of Kinesiology
Louisiana Tech University
P.O. Box 3176
236 Memorial Gym
Ruston, LA 71272
Office: (318)257-5467
Email: mqiao@latech.edu

Members of the Human Use Committee of Louisiana Tech University may also be contacted if a problem cannot be discussed with the experimenters:

Dr. Richard Kordal,
Director, Office of Intellectual Property & Commercialization
Ph: (318) 257-2484,
Email: rkordal@latech.edu

B.3 Assent Consent Form

HUMAN SUBJECTS ASSENT FORM

The following is a summary of the project in which you are asked to participate. Please read this information before signing the statement below.

TITLE OF PROJECT: THE EFFECT OF LATERAL DEVIATION ON TRIPLE JUMP PERFORMANCE

Why is this study being done?
The purpose of this study is to investigate the effect of lateral deviation on triple jump performance within high school and collegiate triple jumpers.

Who will participate in this study?
High school and collegiate triple jumpers between ages 16-24, with least one season training experience with no injuries of the lower extremities in the past 3 months.

What will you be doing?
Interview and Screening: During the interview and screening, you will have the opportunity to discuss the contents of the assent form, as well as ask questions. If you agree to participate in the study, you will be asked question about your health and training history to determine if you are eligible for this study.

7) **Warm up**: You will be allowed a 30-45 minutes warm-up to lower potential risk of injury. A general warm-up will include jogging 1-lap around the local outdoor track followed by active dynamic stretching (15 minutes). A specific warm-up will include drills, buildups/accelerations, and pit drills guided by the lead investigator (15-30 minutes).

8) **Tasks:** you will be randomly ordered for trials and jump in the same order throughout data collection. You will be allowed four jumps at maximum effort. At the conclusion of the trials, you will complete a cool down. The cooldown will include jogging 1-lap around the local outdoor track followed by static stretching. Static stretching will be guided by the lead investigator (10-15 minutes).

9) **Data Collection:** Three measurements will be taken: 1) Jumping distance as it aligns with the midline of the runway area. 2) Jumping distance where the tape is placed at the midline of the take-off board and pulled in the pathway of the landing position of the jump phase. 3) The distance between the midline and landing position for each phase.

What benefits will you receive from participating in the study?

By participating in this study, it will be a better understanding of the effects of lateral deviation on triple jump performance. Also, after data collection, you will be given constructive criticism to help improve your future triple jump performances.

Will there be a possible risk or discomfort?
The following are potential physical risks that may occur during data collection for this study:

- The task may have the risk of a knee injury or spraining the ankle. These risks are minimized because running approach speeds will be self-selected by each participant. Also, you are recommend to wear appropriate knee/ankle brace(s) and required to wear appropriate shoes. Furthermore, the warm-up prepares the lower extremities for activity and decreases the risk or injury. Finally, the risk of injury is minimized because you are required to have at least one season of triple jump training with no history of injury in the past three months.

All above risks are well-known and documented. Procedures are in place to minimize potential risk; however, there is a possibility that you may be subject to risks that have not been mention*. If at any point, you feel the need to withdraw from the study, you will be allowed to stop immediately.*

The participant understands that Louisiana Tech is NOT able to offer financial compensation nor to absorb the costs of medical treatment should you be injured as a result of participating in this research.

The following disclosure applies to all participants using online survey tools: This server may collect information and your IP address indirectly and automatically via "cookies."

I, ____________________, attest with my signature that I have read and understood the following description of the study, "(THE EFFECT OF LATERAL DEVIATION ON TRIPLE JUMP PERFORMANCE)," and its purposes and methods. I understand that my participation in this research is strictly voluntary and my participation or refusal to participate in this study will not affect my relationship with Louisiana Tech University or my grades in any way. Further, I understand that I may withdraw at any time or refuse to answer any questions without penalty. Upon completion of the study, I understand that the results will be freely available to me upon request. I understand that the results of my survey will be confidential, accessible only to the principal investigators, myself, or a legally appointed representative. I have not been requested to waive nor do I waive any of my rights related to participating in this study.

Signature of
Participant____**Date**_____________________

Signature of
Researcher____

CONTACT INFORMATION: The principal experimenters listed below may be reached to answer questions about the research, subjects' rights, or related matters.

Principal Investigator:

Kourtney S. Jones, M.S.
Graduate Teaching Assistant
Department of Kinesiology
Louisiana Tech University
Phone: (251) 654-2356
Email: kjo016@latech.edu

Co-Investigator:

Mu Qiao, Ph.D.
Assistant Professor
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Director, Office of Intellectual Property & Commercialization
Ph: (318) 257-2484,
Email: rkordal@latech.edu

B.4 Data Collection Sheet

THE EFFECT OF LATERAL DEVIATION ON TRIPLE JUMP PERFORMANCE:
Data Collection Sheet

Subject #______________ Bio.Sex: _____ Height________ Weight__________

Age_______ Training Age_______ Athletic Status: HS Collegiate

Runway Distance:

Trial #	HED	HAD	SED	SAD	JED	JAD	TJED	TJAD	Time(s)
1									
2									
3									
4									

Comments:

Subject #______________ Bio.Sex: _____ Height________ Weight__________

Age_______ Training Age_______ Athletic Status: HS Collegiate

Runway Distance:

Trial #	HED	HAD	SED	SAD	JED	JAD	TJED	TJAD	Time(s)
1									
2									
3									
4									

Comments:

Subject #______________ Bio.Sex: _____ Height_________ Weight__________

Age_______ Training Age_______ Athletic Status: HS Collegiate

Runway Distance:

Trial #	HED	HAD	SED	SAD	JED	JAD	TJED	TJAD	Time(s)
1									
2									
3									
4									

Comments:

APPENDIX C

C.1 IRB Approval Form

LOUISIANA TECH
UNIVERSITY

MEMORANDUM

OFFICE OF SPONSORED PROJECTS

TO: Ms. Kourtney Jones and Dr. Mu Qiao

FROM: Dr. Richard Kordal, Director of Intellectual Property & Commercialization (OIPC)
rkordal@latech.edu RRK

SUBJECT: HUMAN USE COMMITTEE REVIEW

DATE: May 7, 2019

In order to facilitate your project, an EXPEDITED REVIEW has been done for your proposed study entitled:

"The Effect of Lateral Deviation on Triple Jump Performance"

HUC 19-102

The proposed study's revised procedures were found to provide reasonable and adequate safeguards against possible risks involving human subjects. The information to be collected may be personal in nature or implication. Therefore, diligent care needs to be taken to protect the privacy of the participants and to assure that the data are kept confidential. Informed consent is a critical part of the research process. The subjects must be informed that their participation is voluntary. It is important that consent materials be presented in a language understandable to every participant. If you have participants in your study whose first language is not English, be sure that informed consent materials are adequately explained or translated. Since your reviewed project appears to do no damage to the participants, the Human Use Committee grants approval of the involvement of human subjects as outlined.

Projects should be renewed annually. ***This approval was finalized on May 7, 2019 and this project will need to receive a continuation review by the IRB if the project continues beyond May 7, 2020.*** **ANY CHANGES** to your protocol procedures, including minor changes, should be reported immediately to the IRB for approval before implementation. Projects involving NIH funds require annual education training to be documented. For more information regarding this, contact the Office of Sponsored Projects.

You are requested to maintain written records of your procedures, data collected, and subjects involved. These records will need to be available upon request during the conduct of the study and retained by the university for three years after the conclusion of the study. If changes occur in recruiting of subjects, informed consent process or in your research protocol, or if unanticipated problems should arise it is the Researchers responsibility to notify the Office of Sponsored Projects or IRB in writing. The project should be discontinued until modifications can be reviewed and approved.

Please be aware that you are responsible for reporting any adverse events or unanticipated problems.

A MEMBER OF THE UNIVERSITY OF LOUISIANA SYSTEM

P.O. BOX 3092 • RUSTON, LA 71272 • TEL: (318) 257-5075 • FAX: (318) 257-5079

AN EQUAL OPPORTUNITY UNIVERSITY